

IMPROVED BONDING ARRANGEMENT AND
METHOD FOR LTCC CIRCUITRY

STATEMENT OF GOVERNMENT INTEREST

This invention was made with Government support under Contract F33657-97-LTCC-0030 awarded by the Department of Defense. The Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

Field of the invention

[0001] The invention in general relates to the field of LTCC (low temperature cofired ceramic) circuitry.

Description of related art

[0002] An LTCC circuit is comprised of a plurality of ceramic layers with passive and/or active components and stacked together to form a module, with each ceramic layer containing thick film printed circuitry metallization, generally gold or silver. The ceramic layers include conductive vias for making electrical contact between layers and the ceramic layers are cofired at a temperature high enough to sinter the layers, yet low enough so as prevent flowing or melting of the metallization. The result of the firing is to form a rigid monolithic structure.

[0003] LTCC circuits have high packing density, can be customized to meet desired applications, are cost effective, reliable and can be controlled with respect to dielectric values. The LTCC allows for integration of digital and RF, stripline and microstrip circuits in a single light weight 3-D package. Such LTCC circuits are

used for high frequency applications in both military as well as commercial devices.

[0004] In order to electrically connect the LTCC structure to other circuitry, wire or ribbon leads are bonded to conductors on the surface of the structure for connection to the other circuitry. A problem often arises however in that the bonded leads may form a poor contact with, or pull loose from, the conductors. This is due to the fact that the conductors contain one or more additives to promote conductor adhesion to the ceramic base layer and it is these additives which degrade the bonding of the leads.

[0005] It is therefore a primary object of the present invention to provide a LTCC structure with much improved lead bondability.

SUMMARY OF THE INVENTION

[0006] An LTCC structure in accordance with the present invention consists of a plurality of stacked layers of ceramic material including metallization in predetermined patterns on and through the layers. The stacked layers include a plurality of exposed electrical conductors to which leads are to be bonded. The conductors are of a metal which includes one or more additives to promote adhesion to the ceramic layer on which the conductors are deposited. A bonding metal layer is deposited on top of the conductors at predetermined locations and is of the same metal as the conductors, however devoid of the one or more additives. The leads are then bonded to the bonding metal layer for improved bonding performance.

[0007] The bonding metal layer may be deposited and may be cofired with the stack of ceramic layers. Alternatively, the stack may be cofired and the bonding metal layer subsequently deposited and thereafter be fired in a second firing of the stack

[0008] Further scope of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood, however, that the detailed description and specific example, while disclosing the preferred embodiment of the invention, is provided by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art, from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will become more fully understood from the detailed description provided hereinafter and the accompanying drawings, which are not necessarily to scale, and are given by way of illustration only, and wherein:

[0010] Fig. 1A is an exploded view of an LTCC structure.

[0011] Fig. 1B illustrates the structure of Fig. 1A in a fired modular form.

[0012] Fig. 2 is a cross-sectional view through conductors of the structure of Fig. 1, illustrating an embodiment of the present invention.

[0013] Fig. 3 is a view of an active device on an intermediate layer of the LTCC structure.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0014] Referring now to Fig. 1, there is illustrated an LTCC structure 10 which is comprised of a plurality of ceramic layers 12 to 17, each having a pattern of metallization. It is to be noted that

structure 10 does not represent an actual circuit but is presented to show typical components which may be placed on the individual ceramic layers. Further, in the description to follow, the metallization will be described using gold, by way of example.

[0015] Bottom layer 12 includes a ground plane 20 having voids 21 where a ground plane is not desired. Layer 13 has metallization areas 24 for the mounting of active devices (not shown), and connected to passive devices such as capacitors 26 by means of conductors 27. Surrounding metallization areas 24 are vias 28 which are vertical apertures in the layer, filled with a specially formulated conductive material for making electrical contact with components on different layers.

[0016] Layer 14 includes an opening, or cavity, 30 to accommodate any active devices on metallization areas 24 on the previous layer, and includes a plurality of conductor pads 32 to which leads from those active devices will be connected. In addition to vias 28, layer 14 also illustrates conductors 36, some of which include passive devices in the form of resistors 38. The next two layers 15 and 16 both include vias 28 and respective cavities 42 and 44, providing access to the active devices.

[0017] The top, or surface layer 17 includes cavity 46 and vias 28 to which are connected various conductors 50. Some conductors 50 include resistors 52 in their path while other conductors 50 include metallization areas 54 for placement of active devices. Further, layer 17 illustrates a plurality of conductor pads 56, connected to components on a previous layer or layers and to which will be connected leads for connection to other circuitry in a system. Similarly, various conductors 50 will also be used for this purpose.

[0018] In the manufacture of the LTCC structure 10, sections of green (unfired) ceramic tape of an appropriate size for processing are cut from a larger roll. Vias are formed, such as by a punching process

and filled with the conductive material. The conductors including the conductor pads are applied in desired patterns by a process using patterned screens to which are applied gold paste.

[0019] In order that the gold paste conductor pattern is suitably affixed to the ceramic tape layer, the gold paste includes one or more additives to promote adhesion. Such additives commonly used include copper, bismuth and glass, by way of example, depending upon the formulation of the ceramic material. Any cavities are then formed in appropriate layers, which are then stacked and fired at a temperature of around 850° C to sinter the gold paste and ceramic layers to form the solid unitary module 60 shown in Fig. 1B.

[0020] After firing, leads are bonded to cavity and surface conductors so that the module 60 may be connected to other circuitry of a system. These leads, which may be wires or ribbons, for example, are bonded to the conductors by a process which includes both heat and ultrasonic vibration. A problem arises however, in that, at times, the leads are poorly bonded and eventually come loose, or do not initially bond at all. This may be attributed to the additives which are included in the conductor paste to promote adhesion to the ceramic layer. It is these additives which prevent optimal bonding.

[0021] The present invention obviates this problem by adding a bonding layer of the same metal as the conductor, only in a pure state devoid of any of the additives contained in the conductor. In one embodiment, this bonding layer may be applied to the conductors in a limited bonding area, prior to firing and then be cofired along with the stack of ceramic layers. In a second embodiment the bonding layer may be applied to the conductors in a limited bonding area and may be post fired after the initial firing of the stack of ceramic layers. Any such bonding layer to be applied to conductors on intermediate ceramic layers (such as conductor pads 32 on layer 14 in Fig. 1A) would have to use the cofired option.

[0022] Fig. 2 illustrates a portion of ceramic layer 17, together with a typical gold conductor 50 and gold conductor pad 56, both containing additives for better adhesion to the ceramic under layer 17. In accordance with the present invention, a bonding layer 70 is affixed to a limited bonding area 72 on top of conductor 50 such as by the same screening process for depositing the conductor. Bonding layer 70 is of pure gold devoid of any of the additives contained in conductor 50 and receives wire or ribbon lead 74, attached by the conventional process of heat and vibration, or thermosonic, bonding. The absence of the additives ensures for a positive and strong bond, coupled with good electrical contact to the conductor 50.

[0023] In a similar fashion, bonding layer 76, also of pure gold devoid of any additives, is affixed to a limited bonding area 78 on conductor pad 56 to ensure for a strong bond with lead 89.

[0024] Fig. 3 illustrates the application of the present invention to an intermediate ceramic layer. An active device 84 affixed to metallization area 24 on ceramic layer 13 and extends through cavity 30. Respective bonding layers 86 have been applied to conductor pads 32 and have been cofired with the stack of ceramic layers. Leads 88 of active device 84 are securely bonded to the pure gold bonding layers 86 by thermosonic bonding.

[0025] In actual tests of LTCC lead bonds, the present invention provided improved bondability that were from 10% to 20% stronger than conventional techniques. Further, in some instances of prior art bonding, the leads would not even bond to the conductors, leading to a "no stick" situation. The present invention may reduce such no sticks by as much as 50%.

[0026] The foregoing detailed description merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which,

although not explicitly described or shown herein, embody the principles of the invention and are thus within its spirit and scope.